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ORIGINAL PAPER

Nitrogen pools and cycles in Tibetan *Kobresia* pastures depending on grazing

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Abstract
Kobresia grasslands on the Tibetan Plateau comprise the world's largest pastoral alpine ecosystem. Overgrazing-driven degradation strongly proceeded on this vulnerable grassland, but the mechanisms behind are still unclear. Plants must balance the costs of releasing C to soil against the benefits of accelerated microbial nutrient mineralization, which increases their availability for root uptake. To achieve the effect of grazing on this C-N exchange mechanism, a $^{15}NH_4^+$ field labeling experiment was implemented at grazed and ungrazed sites, with additional treatments of clipping and shading to reduce belowground C input by manipulating photosynthesis. Grazing reduced gross N mineralization rates by 18.7%, similar to shading and clipping. This indicates that shoot removal by grazing decreased belowground C input, thereby suppressing microbial N mining and overall soil N availability. Nevertheless, NH_4^+ uptake rate by plants at the grazed site was 1.4 times higher than at the ungrazed site, because plants increased N acquisition to meet the high N demands of shoot regrowth (compensatory growth: grazed > ungrazed). To enable efficient N uptake and regrowth, *Kobresia* plants have developed specific traits (i.e., efficient above-belowground interactions). These traits reflect important mechanisms of resilience and ecosystem stability under long-term moderate grazing in an N-limited environment. However, excessive (over)grazing might imbalance such C-N exchange and amplify plant N limitation, hampering productivity and pasture recovery over the long term. In this context, a reduction in grazing pressure provides a sustainable way to maintain soil fertility, C sequestration, efficient nutrient recycling, and overall ecosystem stability.

Keywords *Kobresia pygmaea* · Gross mineralization · Nitrogen uptake · ^{15}N labeling · Intensive grazing · Grassland management

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Introduction

The Tibetan Plateau hosts the world's largest and highest grasslands and one of the most sensitive and fragile ecosystems, vulnerable to global environmental change and anthropogenic activities (e.g., Cui et al. 2006; Babel et al. 2014; Chen et al. 2014). The Tibetan grasslands play an important role in ecosystem functioning, e.g., soil carbon (C) storage (ca. 7.4 Pg C), water and soil conservation, and climate regulation (Yang et al. 2008; Lin et al. 2017). Tibetan grasslands support a diversity of plants, livestock, and local pastoral communities (Kang et al. 2007). The alpine Cyperaceae mats of *Kobresia pygmaea* are the major constituent of the Tibetan grasslands and cover an area of 450,000 km^2, ranging from 3000 to nearly 6000 m in altitude (Miehe et al. 2008, 2017). The grazing lawns grow 2–4 cm high and develop a firm closed root system in the upper 30 cm of soil (termed *Kobresia* turf, Kaiser et al. 2008). Consequently, *Kobresia* root mats are characterized by high quantities of roots and rhizogenic